VIRTUAL TESTING DRIVEN DEVELOPMENT PROCESS FOR SIDE IMPACT SAFETY

Stein-Helge Mundal
Dr. Swen Schaub
TRW ORS GmbH & Co. KG
Germany
Christian Amann
BMW AG
Germany
Paper Number: 223

ABSTRACT

A new simulation tool was established and approved by TRW as part of the continuous improvement of the development process. This tool allows the OEM and the system supplier to keep high quality even with further reduced development times. The introduction of the tool in a side air-bag development program makes it possible to ensure high development confidence with a reduced number of vehicle crash tests and late availability of interior component parts.

INTRODUCTION

It is obvious that the development process has to be covered more and more by mathematical simulation and that the successful implementation of these tools is strongly dependent on the accuracy of the models. Therefore a tight cooperation between an OEM having a high accuracy of the structural model and a supplier having the adequate restraint system models will enable an efficient and successful development work. This paper will describe the methodology of the new process established and approved based on a thorax-bag development program together with BMW.

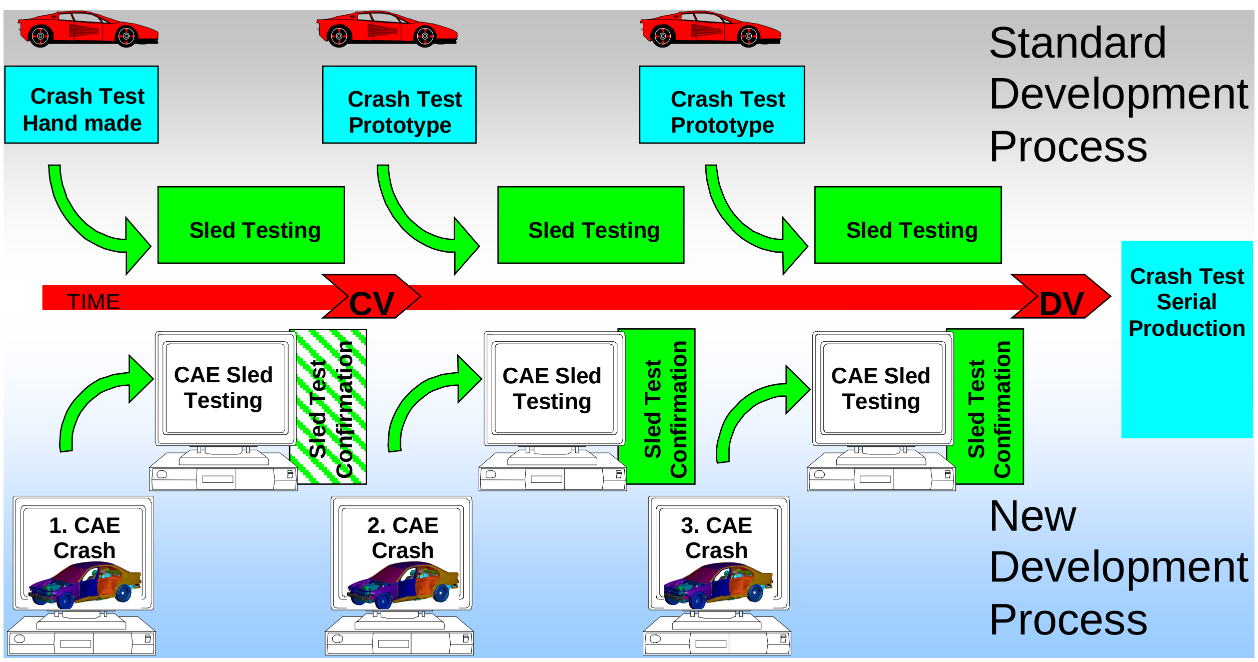

Figure 1. Comparison of a standard process and the new development process

DEVELOPMENT PROCESS

The **Standard Development Process** of a restraint system is based on a high number of full scale crash tests, see figure 1. The first crash test protoype is often a “hand made” car, with parts out of protoype tooling, partly missing trim and other equipment or laminated trim parts as substitution which do not have the designed crash behaviour. In most cases the resulting information from this crash is marginal or even poor for the design of a restraint system. However, it is the only information available at that time and has to serve as input for the restraint system development. A second crash test prototype is usually equipped with first prototype trim parts. A third crash test prototype could be another crash configuration with a prototype. Depending on the markets for which the vehicle is going to be certified, the number of prototype crash tests will increase. A typical problem is also that a prototype crash test has to be repeated due to structural singularities or collapse problems, which every time leads to changed conditions for the restraint system.

Because of the high costs of prototype crash tests, restraint parts have to be included that are already working stable under those conditions. For this reason it is tried to perform the main part of the system improvement in dynamic component tests, like sled testing where a part of the car is built up on a sled and the physics of a crash event is simulated. This is symbolised as green frames in figure 1.

Due to the fact that the sled tests are based on the prototype vehicle crash test, the quality of the tests is strongly related to the results and information from the prototype crash test. Also these component tests require hardware parts of the car interior, like door casings, seats etc. With respect to the development process, these parts are available very late and are relatively expensive because they are also made out of prototype tools.

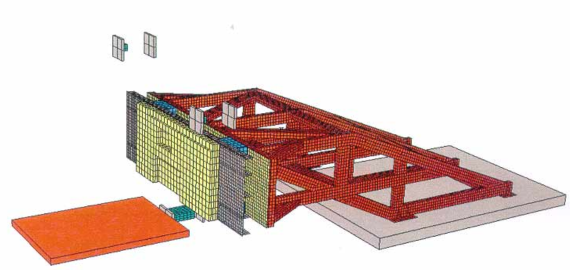

Figure 2. FEM model of the side impact sled test device

Concerning the side impact tests in particular, the design and deformations of the trim parts and seat and their interaction with the occupant has to be simulated in a sled test as well. Depending on the sled test device, the set-up parameters like door intrusion velocity, seat acceleration, pre-deformations of trim panels, stiffness of energy absorbing elements etc. have to be determined/tuned. In general this is an iterative process. The so-called "validation tests" usually comprise three or more tests. After the validation tests are completed, the process of improving the restraint system design can start. During this improvement phase, parameters like bag design, folding pattern, vent hole size or positioning of the restraint system are studied, as well as the performance of the restraint system in different seating positions or impact configurations.

Regarding the **New Development Process** the steps described above take place in the computer. This is symbolised by the computer icons in figure 1. The central part is a detailed CAE model of the TRW side impact sled test device shown in figure 2 that is validated against a series of basic sled tests and additional component tests.

Using the input from a CAE vehicle crash, illustrated in figure 3, the dynamics of the crash can be mapped to the CAE model of the sled test device. This is done by adjustment of the different set-up parameters of the sled test device.

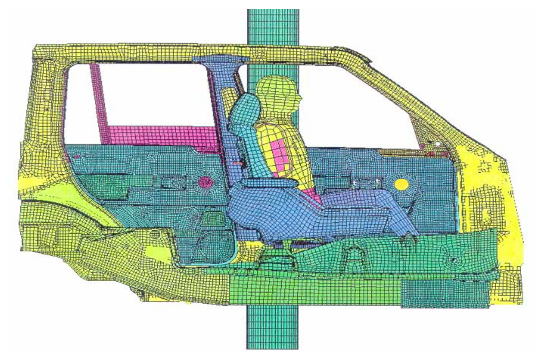

Figure 3. FEM model of the vehicle crash

The necessary parts of the vehicle structure, dummy position and trim panels are cut from the vehicle CAE model and fit directly into the sled CAE model as shown in figure 4.

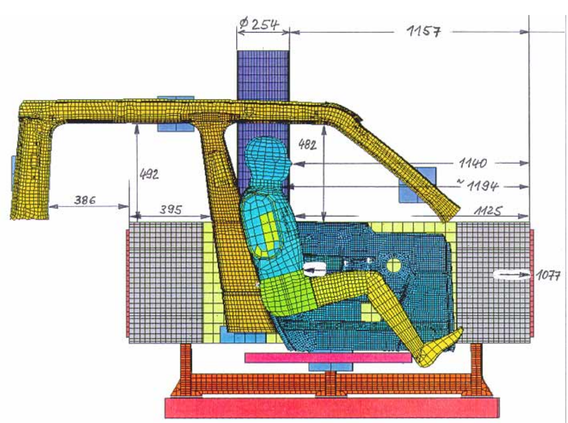

Figure 4. Parts from virtual vehicle implemented in the virtual sled test device

Set-up parameters

Only physical set-up parameters of the sled test device are allowed to be adjusted in the virtual model. That means only the applied materials with known dynamic properties (like foams or aluminium deformation elements) are changed during adaptation of the sled behaviour, in order to stay within the physical limits of the real sled device.

Obviously, all the components (trim panels, seat, dummy, air-bag module) that are implemented in the CAE model of the sled device have to be dynamically validated for the side impact loadcase in advance. It is also important that each component CAE model fulfils a certain level of quality with respect to the real component in order to obtain successful results. Figure 5 shows an example of a CAE model of the folded thorax air-bag module installed behind a rupturing cover of the door panel, which can be seen in figure 6.

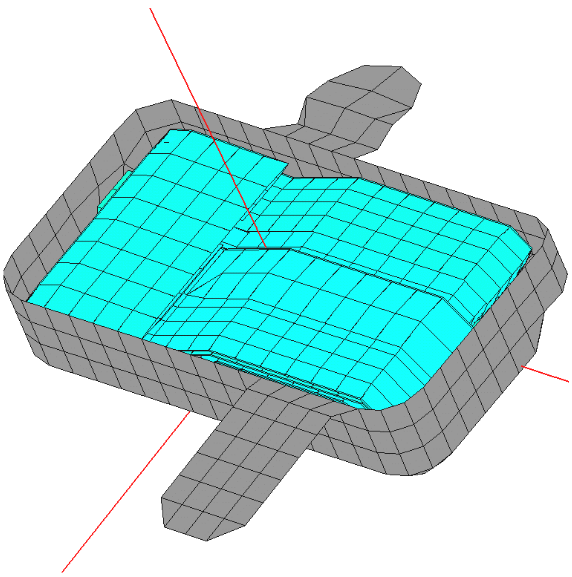

Figure 5. FEM model of the folded thorax-bag module

Even when every single component is well validated, the modeling of the attachments have to be treated with care. After installing the models of all the interior components, as shown in figure 6 the very first sled test is started in the computer.

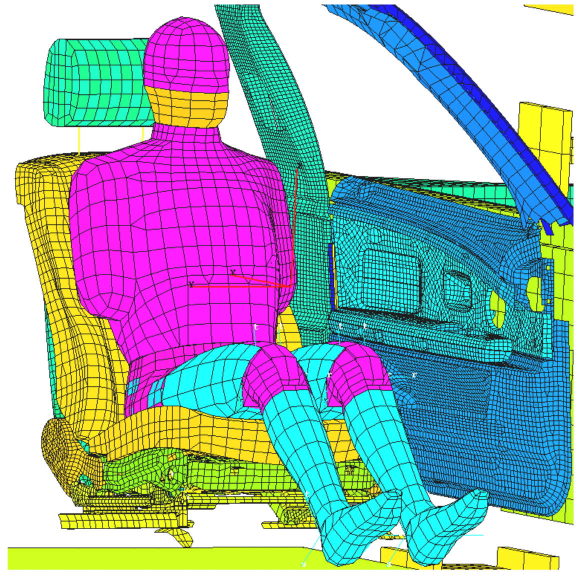

Figure 6. Model prepared for virtual sled testing

Confirmation tests

Today, no commercial crash test simulation software is capable of calculating the inflator exhaust jet or the gas flow inside an air-bag with methods of fluid dynamics. Therefore the risk of fully cancelling dynamic testing of air-bags before launching the production tools is regarded as too high.

Design improvements like additional fabric heat shields, fabric reinforcements, fabric attachments and position of seams are best adapted during a sled test series because those design details strongly depend on parameters like bag folding, inflator characteristics, air-bag cover/door opening behaviour and different loading of the air-bag. Most of these issues are not reliably predictable by simulation only.

As soon as satisfying results in the validated sled CAE model are obtained regarding set-up parameters and component design parameters, the experimental sled testing can run. These tests are used to confirm the virtually improved design with hardware. It is important that the same set-up parameters from the CAE model are also used in the real sled test. Drawings from the final CAE model (see figure 4) are used for the test set-up. An example of the CAE sled door set-up is shown in figure 7.

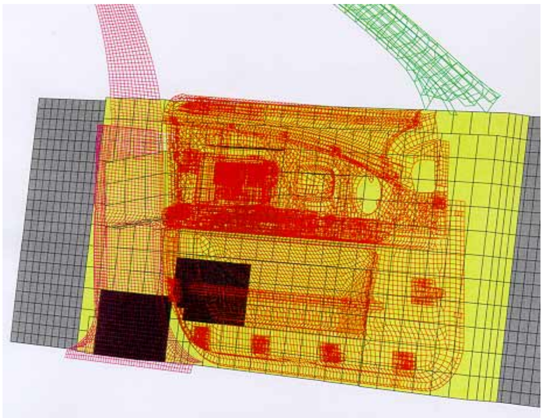

Figure 7. Final computer improved design of the sled door

The transfer of all the details of the set-up parameters requires a close cooperation between the different teams involved. Figure 8 shows the set-up of the real sled test door designed according to the model.

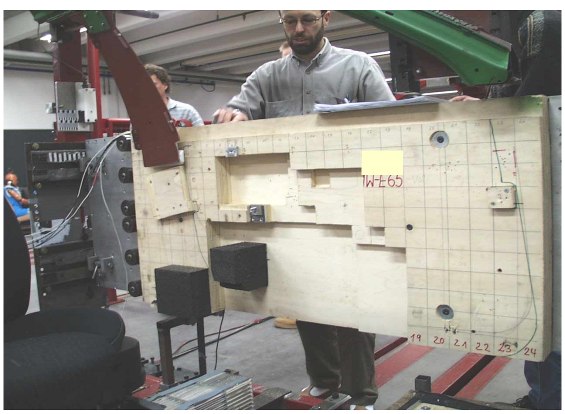

Figure 8. Computer improved design of the real sled door for the first confirmation test

In this way, the field of experimental testing and mathematical simulation is brought much closer. The final set-up of the complete sled model is shown in figure 9. The corresponding real sled test set-up is shown in figure 10.

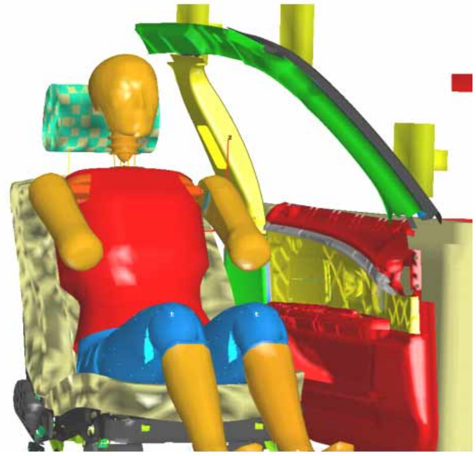

Figure 9. Final set-up of the complete sled model

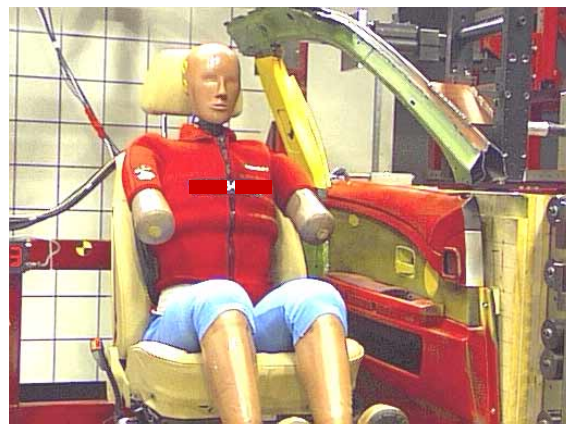

Figure 10. Final set-up of the corresponding real test

Regarding the overall loading of the occupant in a side impact, the door intrusion velocity is one of the main parameters. This parameter can vary a lot depending on the location in the door and the local deformations during an impact. In general more positions should be taken into account. To get good performance out of a thorax-bag, the closing gap between the occupant and the door panel during the deployment has to be well simulated. To secure good results in the final vehicle crash, a good correlation to the CAE crash is required. Additionally the simulation of the closing gap has to be representative in the virtual sled test as well as in the real sled test.

In this case, two intrusion velocities in the air-bag area were used as a target corridor for the sled test. Due to the very high dynamic of the door motion, the accuracy of the signals captured using standard crash measurement techniques is not proven. Figure 11 shows the correlation of the door intrusion velocity from the CAE vehicle crash, the sled model and the final sled test. The two solid lines from the CAE crash form a corridor for the target intrusion velocity of the sled model shown as the dashed line. The two dotted lines are the integrated signals from two accelerometers in one sled test at the same position.

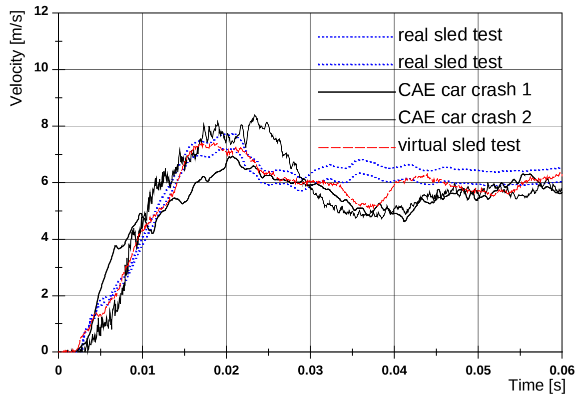

Figure 11. Door intrusion velocities

A design giving good performance according to the virtual sled testing is chosen for the confirmation test. The most important parameter for the performance of an air-bag is the internal pressure during the loading. In the virtual sled testing, the internal static pressure is calculated. In the real sled testing, the total internal pressure is captured by means of a pressure transducer. Due to the aerodynamic influence in the real test and some modeling simplifications, a correlation in the first two milliseconds is not expected. After all, the confidence level of the process is strongly related to the correlation of the internal bag pressure. Figure 12 shows the correlation of the bag pressure from the virtual testing and the pressure measured in two repeated tests.

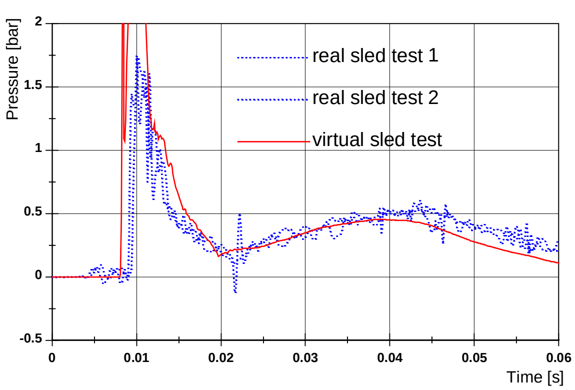

Figure 12. Internal bag pressure

CONCLUSION

By following the new development process, no vehicle crash test is required before launching the production tools for the restraint system. A high level of confidence is obtained by confirming a small number of chosen test configurations by means of experimental sled testing. Due to the accuracy of the sled model and the added components, the set-up parameters of the sled device are improved in the computer. Validation tests, consuming time and costs, can fully be cancelled. Experimental sled tests based on a crash test of an early prototype vehicle are cancelled. The restraint system's design parameters are improved during the virtual sled testing even before the first prototypes of hardware parts (seat and trim panels) are available. Experimental sled testing only starts after satisfying results from the virtual sled testing are obtained.

The field of mathematical modeling and experimental testing is brought much closer. The integration of a virtual product development has reached a new level with the virtual development driving the process. Information from both virtual and real sled testing with a lower number of parameters and dispersion compared to full scale crashes has brought a deeper understanding of the complex side impact thematic.

ACKNOWLEDGEMENTS

Acknowledge to the door trim supplier Firmengruppe Dräxlmaier (DRX) and the Industrieanlagen-Betriebsgesellschaft (IABG) for the contribution and the close cooperation during the work.